Water limitation of enery crop rotations – A simulation study for German conditions

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Introduction and Hypotheses

General Background

European and German policy has focused on promoting renewable energy use

⇨ increased cultivation of biomass crops for use in biogas plants

Biomass production (for biogas plants) is mainly based on maize monoculture

⇨ environmental problems (e.g. NO_3-leaching and decrease of soil carbon stocks and soil humus)

Global Hypothesis

Energy crop rotations or grassland are under certain regional conditions an alternative to maize monoculture

- Supporting assumptions and resulting hypotheses-

❖ Maritime sites (northern parts of Germany):

Relatively low average temperatures per year (~8.5 °C)

⇨ suboptimal region for cultivating maize - alternatives?

High annual rainfall of 750-800 mm (evenly drstributed)

⇨ energy crop rotations with high water requirement possible (winter intercroping)

Large areas of permanent grassland (high groundwater level)

⇨ enough dry matter production for use in biogas plants

❖ Continental sites (eastern and central parts of Germany):

Higher temperatures during vegetation period

⇨ favours maize cultivation

Lower annual rainfall

⇨ maize with a high water use efficiency (C_4-plant)

Materials and Methods

Modular Model Approach

❖ Module for Evapotranspiration:

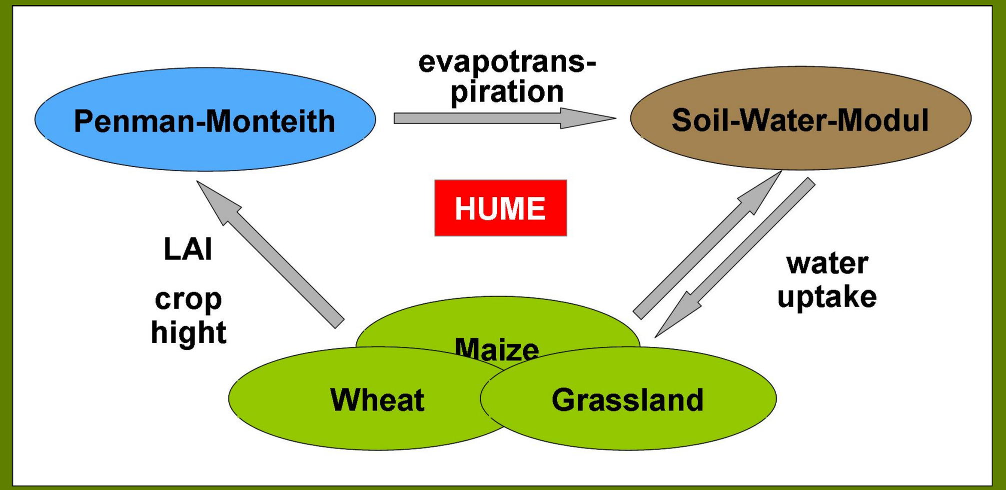
based on Penman-Monteith

❖ Module for soil-water balance:

potential based layer model

❖ Modules for plant growth and quality:

wheat (based on CERES Wheat), grassland and forage maize (derived from the model FOPROQ[1])



Implemented in an object orientated modelling environment (HUME[2]), crop objects as linked list

Simulation study

❖ Simulation period:

36 years (1970 – 2006)

❖ 2 climates (sites):

maritime (776 mm, 8.7 °C), continental (508 mm, 9.2 °C)

❖ 1 soil typ:

luvisol (23 % field capicity)

❖ 3 crop rotations:

maize monoculture, grassland (4 cuts), energy crop rotation (wheat for silage use, overwintering rye grass (2-3 cuts), maize)

Calculation of dry matter production with particular consideration of water use efficiency

Results and Discussion

Dry matter productivity

DM [t/ha] (CV [%])	maritime	continental
Grassland	12.7 (6.9)	9.6 (15.5)
Maize	15.8 (15.0)	12.1 (24.3)
Crop rotation	15.7 (22.9)	12.2 (23.3)

Dry matter (DM)

• maize ≈ crop rotation > grassland
• maritime > continental

Coefficient of variation of dry matter (CV)

• crop rotation ≥ maize > grassland
• continental > maritime

Water balance

[mm/a]	T	E	D
Grassland, maritime	318	129	279
Maize, maritime	201	239	300
Crop rotation, maritime	248	205	280
Grassland, continental	291	109	70
Maize, continental	141	234	111
Crop rotation, continental	199	191	84

Transpiration (T)

• grassland > crop rotation > maize
• maritime > continental

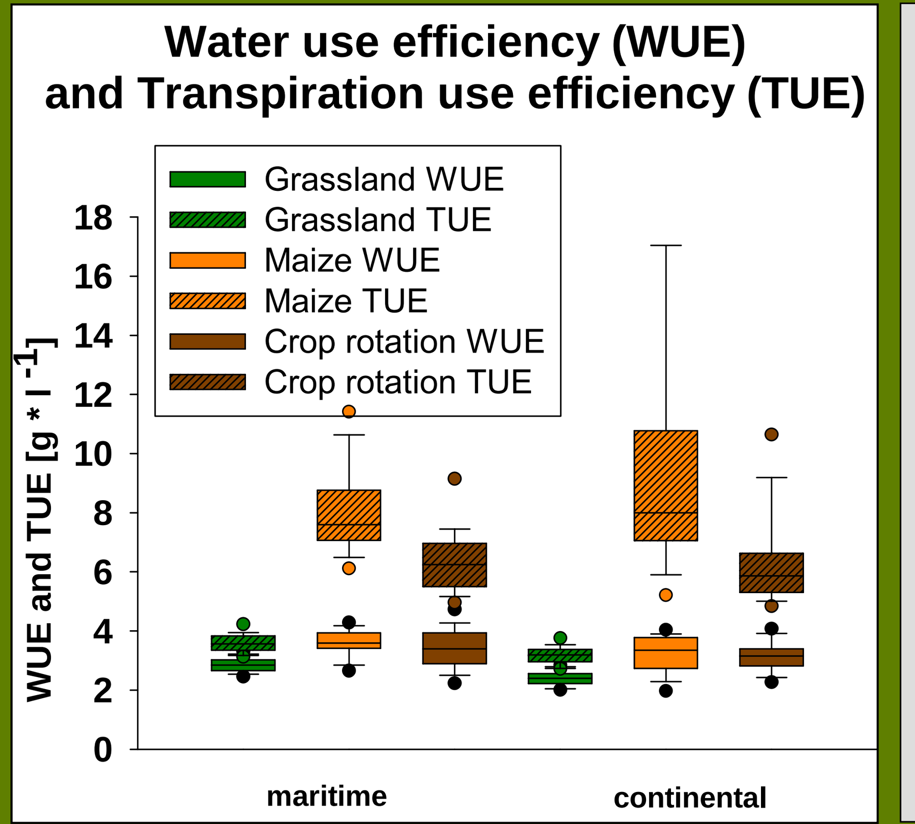
Evaporation (E)

• maize > crop rotation > grassland
• maritime ≥ continental

Drainage (D)

• maize > crop rotation ≥ grassland
• maritime > continental

Water use efficiency



Water use efficiency (WUE)

• maize ≥ crop rotation ≥ grassland
• maritime ≈ continental

Transpiration use efficiency (TUE)

• maize > crop rotation > grassland
• maritime ≈ continental

Conclusions and Outlook

Maritime sites

Concerning the dry matter productivity this simulation study shows that crop rotations can be an alternative to maize monoculture. ✓ ✓ ✓

higher transpiration use effiency and growth rates of maize is balanced by a longer growth period and a total higher transpiration of the crop rotation

Continental sites

Dry matter productivity of maize monoculture and crop rotation also similar ???

preliminary simulation result: possible underestimation of soil water demand in the crop rotation due to underestimation of dry matter productivity of rye grass (winter intercroping)

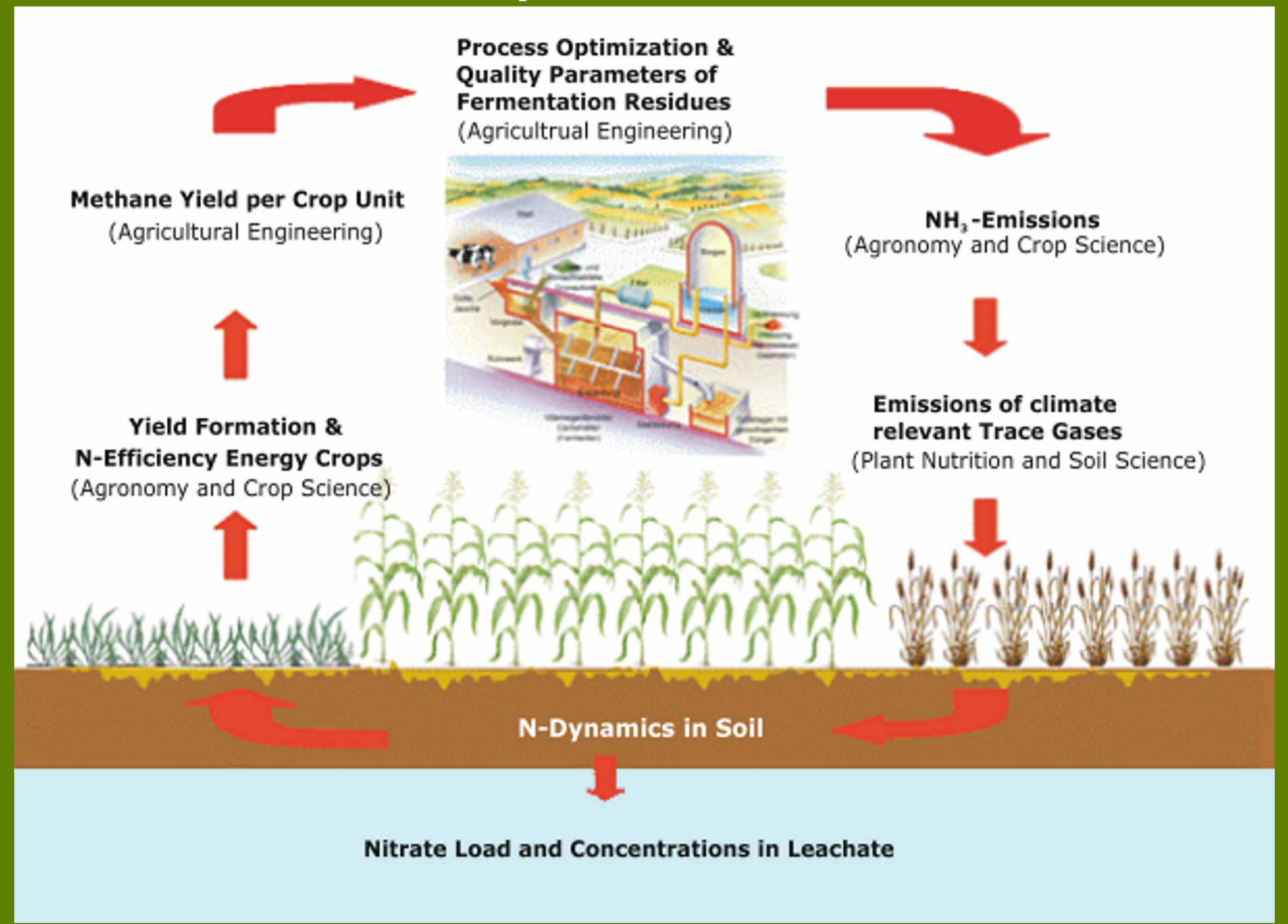
⇨ The simulation model has to be calibrated and evaluated by experimental data.

⇩

Field experiment in progress

Cooperative project (BIOGAS-EXPERT) including a multi-factorial (location, crop rotation, nitrogen-amount, nitrogen-form) field experiment 2006-2009

Project overview



Literatur:

1) Herrmann, A., A. Kornher, and F. Taube 2005. A new harvest time prognosis tool for forage maize production in Germany. Agric. For. Meteorol. 130, 95-111.

2) Kage, H., and H. Stützel. 1999. HUME: An objekt oriented component library for generic modular modelling of dynamic systems. In "Modelling cropping systems". (C. S. M. Donatelli, F. Villalobos, J. M. Villar, ed.), pp. 299-300, Lleida 1999. European Society of Agronomy.

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